ANALYSIS OF THE DROUGHT OCCURRENCE AND ITS IMPACT ON SPRUCE ECOSYSTEMS IN THE ZVOLEN VALLEY AND ITS SURROUNDING IN THE PERIOD 2009–2014

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The present paper deals with the assessment of climate characteristics during the period 2009–2014. The selected localities are situated in sub-montane and montane regions of the Zvolen valley and surrounding presenting a wide altitudinal gradient from 350 m a.s.l. to 1264 m a.s.l. We focused on the evaluation of climatological drought in the period 2009-2014 and moisture assurance of the non-originating planted but nevertheless present spruce forests in the monitored region. Humidity conditions were also studied by using the potential evapotranspiration and climate irrigation index. The dry years were mainly the years 2009, 2012 and 2013, on the other hand the year 2010 was characterized by abundant precipitation. The growing season 2014 was characterized by above-average precipitation abundant and relatively cool summer in contrast to previous years. The evaluation of drought in spruce forests showed that non-originating planted spruce forests in the 2nd and 4th forest vegetation zone will be stressed by drought. We recorded drought stress only in the years 2011 and 2012 in 6th forest vegetation zone. In this forest vegetation zone are spruce forests in the lower limit of ecological optimum. The observations of last years show a higher frequency of extreme weather situations and in the Zvolen valley and its surrounding, in accordance with predictions and scenarios.

Keywords: climate irrigation index, drought index, Norway spruce, moisture assurance

INTRODUCTION

The atmospheric precipitation are an important factor affecting weather and climate zone and one of the basic components of water cycle in nature and water balance in the basin. The precipitation with temperature and other meteorological parameters make the landscape essentially, vegetation cover type the land surface, water management relations of landscape. They are characterized by variability in quantity, quality and distribution in the area and time.

In our climatic conditions the term drought indicates the certain period of time (weeks, months, years), in which falls less precipitation than the corresponding normal. The averages, deviations and their frequency of occurrence are detecting. There is not yet available any official methodology by which it might be quantify the drought and if it occurs to have prompt information about the state of the whole territory affected by drought for operational decision-making. The effect of closed series of consecutive days with precipitation or no precipitation is different than the same amount of precipitation irregular occurrence.

The drought as dangerous natural phenomenon resulting from the lack of atmospheric precipitation in the interaction of increase of evapotranspiration amount becomes a significant problem regarding to projected climate change in various economic and environmental fields of human activity.

The analysis of drought, which is mostly given its most serious impacts in the agricultural sector, focuses mainly on most productive regions of Slovakia. However, several papers (e. g. Sitková *et al.* 2014, Střelcová *et al.* 2011) suggests that forest ecosystems ensuring the highest degree of ecological stability of the country are exposed to the effects of drought as well.

All the more so, if as wood composition of these ecosystems is non-originating resp. individual tree species are beyond their ecological optima (especially 2nd and 4th forest vegetation zone (fvz)). In the present paper we present the assessment of the occurrence of climatological drought and moisture assurance of non-originating spruce stands in the 2nd, 4th and 6th forest vegetation zone in the period 2009–2014 in Zvolen valley and its surrounding.

Characteristics of research site – Zvolen valley and its surrounding

We performed the individual measurements of meteorological characteristics at the stations Arborétum Borová hora, Kráľová nad Zvolenom and Predná Poľana, located in altitudes from 350 to 1264 m a.s.l.

The characteristics of individual sites are given in Table 1. Modified klimadiagramms in the Figure 1 present the differences between the climate of individual vegetation zones. The klimadiagramms represent the course of the long-term monthly average temperatures and precipitation during the reference period 1961–1990.

Zvolen valley is intermountain landscape unit in Slovenské stredohorie region. In the west it is bordered by Kremnické vrchy, in the south by Javorie, Starohorské vrchy in the north, the northeast by Horehronské podolie, in the east by Poľana and Veporské vrchy. Based on the altitude, Zvolen valley belongs to the middle altitude level valley, only small areas falls below 300 m a.s.l. or it exceeds over 500 m a.s.l. based on the altitude (Seko 2009). Climatic conditions of Zvolen valley are primarily determined by its geographical location. According to the climate and geological regionalization of Slovakia, this territory belongs to the warm valley climate, slightly dry to moist. The air temperatures are from -3 to -5 °C in January, from 18.5 to 20 °C in July. The number of summer days is usually 40–50 days. The number of days with snow cover is 50–70. We can included Zvolen valley among the very inverse regions of Slovakia (Lapin, Tekušová 2002). It is influenced by the closed central location of the valley of the Western Carpathians (Mazur, Lukniš 1980) and by the occurrence of the surrounding mountains around the valley. The whole Zvolen valley is typical by the local winds, but it belongs to the least wind region of Slovakia because of the high percentage of days without wind. In Zvolen valley dominates the north wind with an average speed 3.4 $m.s^{-1}$, the valley of Slatina is characterised by northwest wind with an average speed of 4 $m.s^{-1}$. The entire valley has the largest number of foggy days in the year an average of the 80–100 days.

Tab. 1 The meteorological stations TUZVO in region of Zvolen valley and its surroundings

Meteorological station	Altitude [m a. s.l]	Forest vegetation zone	Mean annual temperature [°C] 1961–1990	Mean annual precipitation [mm] 1961–1990
Borová hora	350	2. beach-oak	7,9	651
Kráľová	785	4. beach	5,8	786
Predná Poľana	1264	6. spruce-beach-fir	3,2	1044

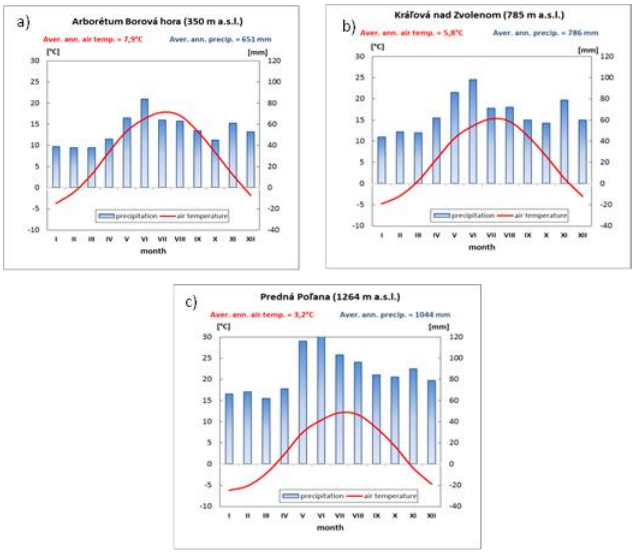

Fig. 1 Klimadiagramm of meteorological stations; a) Arborétum Borová hora, b) Kráľová, c) Predná Poľana

MATERIALS AND METHODS

The measurements of meteorological characteristics are carried at the regional meteorological stations, located in different altitudes in the forest areas of Zvolen valley and its surroundings. To assessment of climatological drought were used indices:

- Climatic moisture indicator $K_{VI-VIII}$ [mm] ($_{VI-VIII}$ - the main growing season) is given by the difference of potential evaporation E_0 and precipitation in the warm half of the year. The processing of potential evapotranspiration is calculated by Penman-Montheit.
- The simple drought index E_0/P (E_0 - potential evaporation, P - precipitation). In this case, the annual means resp. the totals were used.
- The moisture assurance of Norway spruce was established by comparing of precipitation totals during the growing season (from April to September) with a minimum required precipitation total during this period (300 mm) Ambros (ex Škvarenina *et al.*, 1995).
- Moisture assurance index of the Norway spruce by De Martone (ex Hanish, 1990):

$$\frac{\text{annual precipitation [mm]}}{\text{average annual air temperature [°C]} + 10}$$

Insufficient moisture assurance means when the index falls below 60 yearly.

RESULTS

The evaluation of climatological drought

The basics of the water balance can be expressed by climatic moisture indicator K, according which the irrigation conditions are characterized by the different of potential evaporation (E_0) and precipitation. Positive values of E_0–P characterize the lack of moisture and negative values the excess of moisture. Figure 2 shows the climatic moisture indicators for the meteorological stations TUZVO representing the different forest vegetation zones. The increase of altitude causes the precipitation totals increase and the value of radiation balance decrease, therefore the climatic moisture indicator decreases. We can observe the significant differences in values between the climatic moisture indicator monitored between the growing season. We recorded mostly negative values in the warm half of 2010 and only positive values in other warm half years. Almost in the all monitored periods we recorded decreasing due to the altitude. It confirms the fact that air temperature decreases and precipitation totals increases by the increase of altitude (Minďáš, Škvarenina 2003).

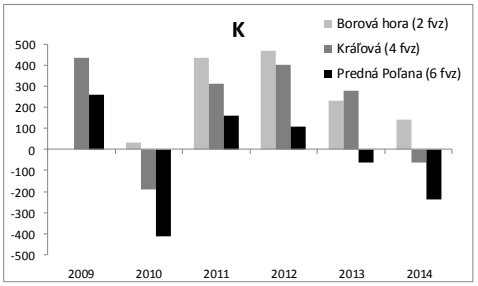

Fig. 2 Climatic moisture indicators for regional meteorological stations TUZVO during the warm half years 2009–2014

The ratio between the potential evapotranspiration and precipitation totals (single drought indices E_0/P) can be considered as an indicative indicator of water balance changes in natural ecosystems within a country. The drought indices >1 is the condition of negative climatic water balance, while the drought indices <1 means that the precipitation amount is higher than the maximum evaporation from vegetation and surface. The figure 3 presents the development of the average values of simple drought indices in the individual forest vegetation zones. Consequently, we can observe the occurrence of aridity in the 2nd fvz in the all monitored years. The analysis showed the occurrence of drought in other forest vegetation zones in the summer of 2009, 2011 and 2012. Consequently, the precipitation totals were significantly higher in 2010.

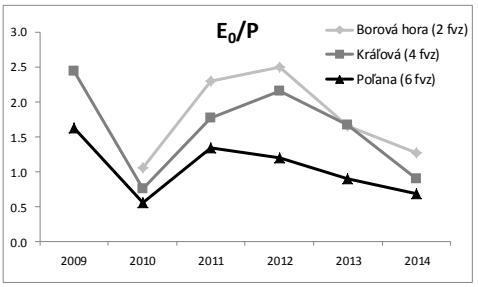

Fig. 3 The ratio between the potential evapotranspiration (E_0) and precipitation totals (P) during the years 2009–2014 in the individual forest vegetation zones.

Moisture assurance of the spruce ecosystems

The indication of drought by using of above mentioned indices is sufficiently informative value from the climatic point of view. However, the method used as a practical solution in forest practice has limits in some respects. Especially the fact that the actual transpiration resp. evapotranspiration of forest stands differs from the potential transpiration resp.

evapotranspiration by specific physiology of individual species. Norway spruce (*Picea Abies*) is one of the most endangered forest tree species in terms of expected large-scale impacts of climate change in the future in interaction with the development of biotic pests (their development is positively influenced by this change). This species, naturally occurring in mountainous altitudes of West Carpathians, was often getting inappropriately to forest wood composition already in the 2nd fvz due to various reasons. But there is a frequent occurrence of precipitation deficit as it was noted in above mentioned characteristics. It leads to significant weakening of these forests species and subsequently to the attack by biotic pests.

Table 2 presents the values of the moisture assurance indices of spruce and the cumulative precipitation amount during the growing season. The results in the table suggest that drought stress of spruce caused by lack of precipitation occurred in the monitored period. According to the values of the cumulative precipitation amount the drought stress was significant in the 2nd and 4th fvz. The drought stress because of the lack of precipitation was not observed in 6th fvz. The drought was occurred in the lower forest vegetation zones equally in 2009 and 2012. In the other years, the lack of precipitation according to the chosen criteria did not occur in the growing season.

Tab. 2 The evaluation of moisture assurance of Norway spruce by using moisture assurance index (MA) and cumulative precipitation amount (CPA) in the growing season (April–September)

		2009	2010	2011	2012	2013	2014
Borová hora (2. fvz)	Moisture assurance	**36**	**51**	**25**	**27**	**38**	**37**
	Cumul. precipitat. amount	**220**	480	312	**236**	289	404
Kráľová (4. fvz)	Moisture assurance	**43**	63	**31**	**30**	**45**	**46**
	Cumul. precipitat. amount	**246**	609	382	**238**	307	475
Poľana (6. fvz)	Moisture assurance	63	89	**45**	**55**	63	65
	Cumul. precipitat. amount	330	626	436	422	520	530

However, the results suggest different conclusions by evaluating the moisture assurance indices. The indices counted not only precipitation amount but also the air temperature as a parameter referring to the potential evapotranspiration. There is disadvantage that the indices count with the annual period. Therefore it should be considered the extremely low precipitation in time with relatively low evapotranspiration total (e.g. winter or spring) may adversely affect the results. From this perspective, we can conclude that in the monitored period the drought stress occurred in the 2nd and 4th fvz in all years except of the station Kráľová in 2010, which was characterized by extremely high precipitation totals throughout the region and especially in the growing season (Leštianska et al., 2014). Neither 2nd fvz was no exception. On the contrary, the year 2009 was characterized by dry weather even in the 6th forest vegetation zone. In this case, the moisture assurance indices exhibited the favorable conditions. Consequently, the results suggest that the moisture assurance indices of spruce in the form of the annual averages resp. totals are not the right characteristics. When we compared the results of the evaluation of moisture assurance with climatological characteristics, we can observe consistency with a cumulative precipitation amount indices and non-consistency with the moisture assurance indices. Therefore, we can conclude that in assessing of moisture assurance of spruce ecosystems is more appropriate instrument precisely the cumulative precipitation amount in the growing season.

Moreover the results showed that spruces planted in non-ecological conditions in 2nd and 4th fvz in the past are subjected to frequent drought stress. We can assume that the conditions for growth of spruce and good health will significantly deteriorate, considering the prognosis and scenarios of climate in the future.

CONCLUSION

The contribution evaluates the incidence of drought in the period 2009–2014 in Zvolen valley territory and surrounding areas in the 2nd, 4th and 6th fvz. We focused on the evaluation of drought by using of classical climatological methods and the drought stress assessment in spruce forest ecosystems. The results showed the appearance of drought episodes in the highest vegetation zones as well (2009, 2011 and 2012). Evaluation of drought in spruce forests showed that non-originating planted spruces in the 2nd and 4th fvz were stressed in the 6th fvz where the vegetation is in the low ecological optima, drought stress was recorded only in 2011 and 2012. We can conclude with respect to projected climate change scenarios that the spruce stands will be at lower altitudes increasingly exposed to drought stress.

Acknowledgement

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